An *ex vivo* comparison of conventional and digital radiography for perceived image quality of root fillings

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Abstract

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Aim To compare the subjective image clarity of two different speed films and the Digora® phosphor plate images with respect to the length and homogeneity of root canal fillings.

Methodology Root canal treatment was performed on 20 extracted permanent mandibular first molar teeth. Standardized images of each tooth positioned in a dried mandible were obtained with E- and F-speed films and Digora® storage phosphor plates (SPP) at 0° and 30° horizontal angulations using the optimal exposure time recommended for each system. Five endodontists and five radiologists rated the image clarity of E- and F-speed radiographs as well as the original and enhanced Digora® images. The data were compared using the Wilcoxon signed rank test ($P < 0.01$). Inter-observer agreement was determined by Cohen's κ.

Results Enhanced digital images were rated as superior followed by E- and F-speed films and then the original digital images for the evaluation of both homogeneity and length ($P < 0.01$) of root canal fillings. Agreement among endodontists and radiologists measurements was high in all of the imaging methods ($\kappa = 0.87$).

Conclusion Perceived image quality of the enhanced Digora® images was superior to the original Digora® and conventional film images for the evaluation of root fillings. However, E-speed film provided a significantly better image clarity in comparison with F-speed and original Digora® images.

Keywords: digital radiography, endodontic treatment, image enhancement, photostimulable storage phosphor system.

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Introduction

Recent improvements in electronic radiographic imaging systems have introduced many potential benefits to endodontic practice. Instantaneous production of high-resolution computer monitor images, enhancement of the captured image without additional radiation exposure, reduction in time between exposure and image interpretation, and digital documentation of patient's records are considerable advantages (Wenzel & Gröndahl 1995, Naoum *et al.* 2003a).

The quality of the image is of fundamental importance in endodontics as it allows the interpretation of root and canal morphology, and particularly the determination of radiographic canal length, as well as final verification of the outcome of root canal treatment (Versteeg *et al.* 1997). Studies have compared Digora® (Soredex Corporation, Helsinki, Finland) images with conventional radiographs for working length determination and accuracy of detection of periapical lesions, and to visualize the root canal anatomy (Cederberg *et al.* 1998, Shearer *et al.* 2001, Naoum *et al.* 2003b). The Digora® system has been found to be more accurate in assessing file length when compared

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with E-speed film (Borg & Gröndahl 1996, Cederberg *et al.* 1998). On the contrary, image quality of the conventional radiography is better than that of the Digora® system to visualize root canal anatomy (Naoum *et al.* 2003a). Most of these evaluations have involved the comparison of E-speed category films or digital systems with each other. However, there is no published data comparing the digital systems with F-speed film for the evaluation of the quality of root fillings.

Therefore, the aim of this study was to compare the subjective image clarity of two different speed films and the Digora® phosphor plate images with respect to the length and homogeneity of root fillings.

Materials and methods

Twenty extracted permanent mandibular first molar teeth were used for the study. One investigator (ES) performed the technical procedures for all teeth. Standard access cavities were prepared using a water-cooled diamond fissure bur in a high-speed hand piece. Gates-Glidden drills sizes 2 and 3 (Dentsply Maillefer, Ballaigues, Switzerland) were used to enlarge the coronal part of the root canals. Working length was determined visually by passing a size 10 K-file just through the apical opening and then 1 mm was subtracted from this length. Root canal preparations were performed using H-files. The master apical file was size 30 and step back was performed in 1 mm increments until size 60. Between each instrument, 1 mL of 2.5% NaOCl was used for irrigation. A total of 10 mL of NaOCl was utilized in each canal. After instrumentation, root canals were filled with the lateral compaction technique using standard size 25 gutta-percha cones and Diaket (3M Espe, Seefeld, Germany) as the root canal sealer. Excess gutta-percha was removed with a hot instrument 1 mm below the canal orifices. The cavities were subsequently restored with a bonding system (Adper Single Bond; 3M Espe, St Paul, MN, USA) and resin composite restoration (Filtek Z 250; 3M Espe).

The root canals of these 20 teeth were imaged using two conventional films and a phosphor plate system with two different angulations. Before radiography, first molars from the left side of 20 dry mandibles were removed and replaced with the root filled teeth. The original adjacent teeth created natural contact points. Radiographic images of experimental teeth were obtained with E- and F-speed (Eastman Kodak, Rochester, NY, USA) films, and blue Digora® storage phosphor plates (SPP) (Soredex Corporation) using the optimal exposure time recommended for each system. E- and F-speed films and SP plates were exposed for 0.40, 0.25 and 0.12 s, respectively. All films and SP plates were exposed at 0° and 30° horizontal angulations with the X-ray unit operating at 65 Kvp, 10 mA (Trophy Radiologie, Vincennes, France) with a 30 cm target film distance and 2.5 mm Al equivalent total filtration. The half value layer was 1.5 mm Al. A plexiglass with 15 mm thickness was inserted between the X-ray tube and the teeth to simulate the effect of soft tissue. A total of 120 images were obtained with E- and F-speed films, and Digora® SPPs. All films were developed in an automatic processor (XR 24; Dürr, Bietigheim, Germany) with fresh solutions (Hacettepe, Ankara, Turkey) for 4 min and 30 s. The processed radiographs were mounted in nontransparent frames and placed on a light box. As magnification of the image has been reported as a disadvantage of radiographs (Vande Voorde & Bjorndahl 1969, Antrim 1983) all radiographs and images were viewed in their original size without magnification. The 0° and 30° conventional radiographs were examined simultaneously as image pairs in a room where the light was dimmed. SP plates were scanned in the Digora® FMX-scanner calibrated for a highest exposure of 0.4 s. The resulting images were analysed with the Digora® for Windows software program. Similarly, the 0° and 30° digital images were displayed and examined simultaneously on a 15-inch super VGA computer monitor in a darkened room to minimize glare. Each original digital image was manipulated by each observer to enhance the contrast and brightness of the image to give the subjectively clearest image of the root canal.

No time limit was set for viewing and the image pair sequence was randomized for evaluators. Five endodontists and five radiologists with a mean age of 35.6 years (range 30–43) and mean clinical experience of 10.4 years (range 6–19) acted as evaluators. The viewing was conducted in two different sessions separated with a period of 1 week.

The evaluators were asked to score the quality of root canal fillings using subjective visual rating first considering length and then homogeneity. A + score was assigned if digital images showed superior clarity of root canal treatment; = if the images showed identical (equal) clarity, or a − score if digital images showed inferior clarity to that of conventional films.

The data were compared using the Wilcoxon signed rank test with an α level of 0.01. Inter-observer

Table 1 Scores of 10 evaluators for image clarity of length and homogeneity of root canal treatment compared using conventional and digital radiography

		No. of ratings	
Image system	Score	Length	Homogeneity
E-speed	+	124	131
	=	23	25
	−	53	44
F-speed	+	70	66
	=	23	21
	−	107	113
Original Digora	+	6	15
	=	0	0
	−	194	185
Enhanced Digora	+	180	184
	=	20	16
	−	0	0

+, Superior clarity; =, similar clarity; −, inferior clarity.

agreement among endodontists and radiologists was also determined by Cohen's Kappa test (κ).

Results

The results presented in Table 1 demonstrate that enhanced digital images were rated superior to the conventional radiographs and original digital images for clarity to visualize both the homogeneity and length of the root fillings ($P < 0.01$). E-speed films showed the second best score followed by F-speed films and original digital images consecutively for both homogeneity and length ($P < 0.01$). Agreement among endodontists and radiologists was high in all of the imaging methods ($\kappa = 0.87$).

Discussion

There are many studies comparing various systems with regard to working length determination and for accuracy of detection of periapical lesions. Most of these studies used objective criteria (measurements) to test the superiority of images produced by various techniques. However, the interpretation of images with respect to clarity is a subjective judgement of its appearance which comprises both the technical qualities of the image as well as experience, skill and visual perception of the viewer. In this study, image clarity was used to compare images produced by Digora® system with conventional radiographs to visualize the length and homogeneity of root canal treatment. In general, raters significantly preferred enhanced digital images for evaluation of both the homogeneity and length of root canal treatment. This is possibly due to the fact that alteration of the contrast and brightness of the original image delineates subtle differences in radiodensity, improving the distinction between tooth structure and the filling materials used in root canal treatment. Although the quality of digital images was rated inferior to conventional images in many studies it has been already reported that digital enhancement may create an image indistinguishable from a film of optimal density (Wenzel 1993).

The results indicate that images of E-speed film were perceived as superior to the corresponding F-speed and original Digora® images for the evaluation of both the homogeneity and length of root canal treatment. When obtaining radiographic images, the purpose of the radiographic receptor (either digital or conventional) is to capture X-ray photon density emerging from the target tissues. This is, in turn, determined by the tissues involved and the radiation source used. Furthermore, geometric requirements should be optimized by the parallelism of the film and object and precise angulations of the X-ray beam. As all of the above-mentioned factors were constant for the present study, the only remaining variable is the image receptor characteristics. This may be explained as the ability of the sensor to capture the emerging photon pattern accurately which is a function of the size of the sensor's capture units. The capture units of conventional (radiographic) emulsion films are essentially the grain size of the film. Faster films have larger grain sizes that result in loss of image sharpness and detail (Langland & Sippy 1973). It is known that Digora® can produce an image around 7 line pairs mm^{-1} while conventional films can attain a spatial resolution exceeding 20 line pairs mm^{-1} (Czajka *et al.* 1996, Huda *et al.* 1997). The difference in spatial resolution therefore may explain the superiority of E- and F-speed films over original Digora images with regard to the evaluation of quality of root fillings.

An empty root canal system is a low contrast object. Huda *et al.* (1997) demonstrated a better low contrast detectability for phosphor plates, probably as a result of better X-ray detection efficiency. Thus, spatial resolution and low contrast detectability act as opposing factors, one favouring film and the other phosphor plates for imaging low contrast structures such as empty root canals. However, in this study, the density of the root canal space filled with gutta-percha and sealer may explain the reason for the superior performance of conventional films over original digital images when evaluating the length of root fillings.

Radiographic visualization is influenced by a number of physical and technical factors. In order to avoid one of the main sources of error in the production of radiographic images a parallel-beam technique with two angles (0° and 30° mesial) was used in the horizontal plane to extrapolate the situation to *in vivo* clinical practice. Results of a previous study indicate that the use of intraradicular contrast primarily improved the diagnostic yield of the 30° radiograph which was related to the increase in canal contrast compensating for the image distortion (Naoum *et al.* 2003a). The increased amount of information obtained from oriented images and optimal viewing conditions may explain the high agreement between observers. The purpose of using 30° horizontal beam angulation in the present study was to provide additional detail not supplied by a 0° angulation, therefore no attempt was made to test the effect of different angulations on diagnostic yield as it is beyond the scope of this study.

All observers were well acquainted with the assessment of root fillings in both conventional and digital images and accordingly high accordance was found between their evaluations. The substantial concordance indicates homogeneity between observers' conception as well.

It is apparent that the Digora system used in this study rated superior to the conventional radiographs only when the images were modified by using the contrast and brightness facilities. Apart from image enhancement mode, E- and F-speed films rated better than original digital images. Several studies have assessed radiographic image clarity by comparing various film speeds with several digital imaging techniques (Cederberg *et al.* 1998, Friedlander *et al.* 2002, Naoum *et al.* 2003a). The results of the present study compared favourably with similar studies. Naoum *et al.* (2003a) reported that enhanced images were superior to conventional radiographs for the visualization of the root canal system with a radiopaque medium. In addition, in the study by Friedlander *et al.* (2002) only the enhanced images of the Digora® system produced better clarity of the file tip. Furthermore, similar results were obtained in studies evaluating the root canal lengths or periapical bone changes with various digital systems and conventional radiography (Huda *et al.* 1997, Borg *et al.* 2000). The main advantage of image processing performed on digital images appear to lie in its ability to remove structured noise, therefore allowing detection of changes that the human eye cannot distinguish on conventional radiographs. If one should consider the extra advantages of lower radiation dose, instant production of radiographic image, particularly in endodontics, and the elimination of the development process and associated processing errors, the use of direct digital intra-oral radiography may increase in endodontic clinics.

Although many digital image manipulation techniques are available in today's technology, there are still no standards with respect to these procedures, and contrast and brightness enhancement in one system may differ from the other. Standard procedures are needed to carry out comparative studies determining the effect of enhancement facilities of the digital systems to clinical interpretation of the images.

Conclusions

The results of the present *ex vivo* study indicate that the perceived image quality of enhanced Digora images was superior to original Digora® and conventional film images for the evaluation of root fillings. On the contrary, conventional E-speed film provided a better image clarity for the evaluation of the homogeneity and length of root fillings in comparison with F-speed and original Digora images.

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